

THE UNITED STATES PATENT AND TRADEMARK OFFICE

In re PATENT APPLICATION of

Inventor(s): Toshifumi HAYAMI and Kazumi NAKANO

Appln. No. 10/669,605

Group Art:

Filed: September 25, 2003

Examiner:

Title: INTERNAL COMBUSTION ENGINE COOLING SYSTEM

VERIFIED TRANSLATION OF PRIORITY DOCUMENT

The undersigned, of the below address, hereby certifies that he/she well knows both the English and Japanese languages, and that the attached is an accurate translation into the English language of the Certified Copy, filed for this application under 35 U.S.C. Section 119 and/or 365, of:

Application No.

Country

Date Filed

2002-321514

Japan

November 5, 2002

Signed this 1st day of August, 2005.

Signature:

Name: Kazumi Komura

Address: 18 Hira-cho, Ogaki-city,

Gifu-pref, 503-0841, Japan



## JAPAN PATENT OFFICE

This is to certify that the annexed is a true copy of the following application as filed with this Office.

Date of Application: November 5, 2002  
Application Number: Japanese Patent Application  
No. 2002-321514  
Applicant(s): DENSO CORPORATION

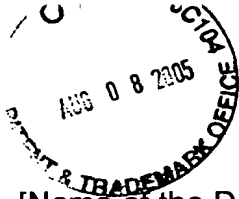
August 15, 2003

Commissioner, Japan Patent Office

Yasuo IMAI

Certificate Issuance No. 2003-3066627

[Name of Document]	Patent Application
[Reference Number]	KD-66868
[To]	Commissioner, Japan Patent Office
[International Patent Classification]	F01P 7/16
[Inventor]	
[Address]	c/o DENSO CORPORATION
	1-1, Showa-cho, Kariya-city, Aichi-pref.
[Name]	Kazumi NAKANO
[Applicant]	
[Identification Number]	000004260
[Name]	DENSO CORPORATION
[Agent]	
[Identification Number]	100089738
[Patent Attorney]	
[Name]	Takenao HIGUCHI
[Indication of Fees]	
[Prepayment Book Number]	013642
[Amount of Payment]	¥21,000
[List of Submitted Articles]	
[Name of Article]	Specification 1
[Name of Article]	Drawings 1
[Name of Article]	Abstract 1
[Request for Proof]	Needed



[Name of the Document] Specification

[Title of the Invention] Internal Combustion Engine Cooling System

[Claimed Scope for Patent]

[Claim 1] An internal combustion engine cooling system comprising:

a radiator that receives cooling water from an internal combustion engine, cools the cooling water and returns the cooled cooling water into the internal combustion engine;

a coolant passage connecting the internal combustion engine and the radiator, and including an inlet passage through which the cooling water flows from the internal combustion engine into the radiator, and an outlet passage through which the cooling water flows from the radiator into the internal combustion engine;

a bypass passage connecting the inlet and the outlet passage to make the cooling water discharged from the internal combustion engine bypass the radiator;

a flow control valve placed at a junction of the outlet passage and the bypass passage to control radiator flow rate at which the cooling water flows through the radiator and bypass flow rate at which the cooling water flows through the bypass passage;

a water pump placed in the inlet or the outlet passage to circulate the cooling water through the internal combustion engine and the radiator;

a desired coolant temperature setting means for setting a desired coolant temperature (normal desired coolant temperature) of the cooling water flowing through the outlet passage; and

a coolant temperature control means capable of controlling temperature of the cooling water flowing through the outlet passage on the basis of the desired coolant temperature set by the desired coolant temperature setting means;

wherein the desired coolant temperature setting means changes the desired coolant temperature according to operating condition of the internal

combustion engine, traveling condition of a vehicle mounted with the internal combustion engine, and ambient condition.

[Claim 2] The internal combustion engine cooling system according to claim 1, wherein the desired coolant temperature setting means sets a desired coolant temperature, for an uphill traveling mode, different from the normal desired coolant temperature when the vehicle is traveling in the uphill traveling mode, and sets a desired coolant temperature, for a downhill traveling mode, different from the normal desired coolant temperature when the vehicle is traveling in the downhill traveling mode.

[Claim 3] The internal combustion engine cooling system according to claim 2, wherein the desired coolant temperature setting means sets a desired coolant temperature lower than the normal desired coolant temperature when the vehicle is traveling in the uphill traveling mode.

[Claim 4] The internal combustion engine cooling system according to claim 2, wherein the desired coolant temperature setting means sets a desired coolant temperature higher than the normal desired coolant temperature when the vehicle is traveling in the downhill traveling mode.

[Claim 5] The internal combustion engine cooling system according to claim 1, wherein the desired coolant temperature setting means sets a desired coolant temperature, for a transient traveling state, different from the normal desired coolant temperature, when the vehicle is in the transient traveling state, and sets a desired coolant temperature, for a steady traveling state, different from the normal desired coolant temperature, when the vehicle is in the steady traveling state.

[Claim 6] The internal combustion engine cooling system according to claim 5, wherein the desired coolant temperature setting means sets a desired coolant temperature lower than the normal desired coolant temperature when the vehicle is in the transient traveling state.

[Claim 7] The internal combustion engine cooling system according to claim 1, wherein the desired coolant temperature setting means sets a desired coolant

temperature different from the normal desired coolant temperature according to altitude level as an ambient condition.

[Claim 8] The internal combustion engine cooling system according to claim 7, wherein the desired coolant temperature setting means decreases a desired coolant temperature below the normal desired coolant temperature with the increase of altitude.

[Claim 9] The internal combustion engine cooling system according to claim 1, wherein the desired coolant temperature setting means sets a desired coolant temperature, for humidity as the ambient condition, different from the normal desired coolant temperature.

[Claim 10] The internal combustion engine cooling system according to claim 9, wherein the desired coolant temperature setting means increases a desired coolant temperature beyond the normal desired coolant temperature as humidity increases.

[Claim 11] The internal combustion engine cooling system according to claim 1, wherein the desired coolant temperature setting means sets a desired coolant temperature, for intake temperature as the ambient condition, different from the normal desired coolant temperature.

[Claim 12] The internal combustion engine cooling system according to claim 11, wherein the desired coolant temperature setting means decreases a desired coolant temperature below the normal desired coolant temperature as intake temperature increases.

[Claim 13] The internal combustion engine cooling system according to claim 1, wherein the desired coolant temperature setting means sets a desired coolant temperature, for combustion mode, different from the normal desired coolant temperature when the internal combustion engine is of a direct-injection type.

[Claim 14] The internal combustion engine cooling system according to claim 13, wherein the desired coolant temperature setting means sets a desired coolant temperature for a stratified-charge combustion mode higher than a normal coolant temperature for a uniform-charge combustion mode.

[Claim 15] The internal combustion engine cooling system according to claim 1, wherein the desired coolant temperature setting means sets a desired coolant temperature, for combustion mode, different from a normal desired coolant temperature when the internal combustion engine is of a lean-burn type.

[Claim 16] The internal combustion engine cooling system according to claim 15, wherein the desired coolant temperature setting means sets a desired coolant temperature higher than a normal desired coolant temperature for a stoichiometric combustion mode when the lean-burn internal combustion engine is operating in a lean-burn combustion mode.

[Detailed Description of the Invention]

[Technical Field of the Invention]

The present invention relates to an internal combustion engine cooling system for properly controlling the temperature of the cooling water.

[Description of the Related Art]

Internal combustion engine cooling systems are disclosed in JP-A-2000-45773 and JP-A-5-288054.

The internal combustion engine cooling system disclosed in the former reference has a bypass passage bypassing the radiator and provided with a flow control valve, and keeps the coolant for cooling an internal combustion engine at an elevated temperature to reduce frictional resistance and fuel consumption. The internal combustion engine cooling system disclosed in the latter reference prevents knock by decreasing the desired inlet temperature, i.e., the desired temperature at the inlet of a coolant circulating circuit, of the coolant when knock begins in the internal combustion engine.

[Reference 1] JP-A-2000-45773 (pages 2, 3)

[Reference 2] JP-A-5-288054 (pages 2, 3)

[Problem to be Solved]

Although the former prior art internal combustion engine cooling system is able to reduce frictional resistance and fuel consumption by keeping the coolant at an elevated temperature, the coolant of an elevated temperature

tends to cause knock. The latter prior art internal combustion engine cooling system decreases the desired coolant temperature by a predetermined fixed temperature upon the detection of knock while the internal combustion engine is in a high-load operation and the coolant temperature is in a middle temperature region. However, since the coolant temperature is decreased by the fixed temperature, the coolant cannot be adjusted to an optimum temperature, and the fixed temperature can be insufficient or excessive depending on the variation of parameters such as those indicating the operating condition of the internal combustion engine and the quality of the fuel. Since this coolant temperature control increases or decreases the coolant temperature gradually, the coolant temperature control is not necessarily able to deal properly with operating conditions, traveling modes or environmental conditions, and causes knock in a coolant temperature range near a knock-limit temperature above which knock occurs.

Accordingly, the present invention addresses the above problem. It is an object of the present invention to provide an internal combustion engine cooling system capable of keeping an internal combustion engine at its most efficient temperature by properly regulating the temperature of the cooling water for cooling the internal combustion engine according to various conditions, and of reducing fuel consumption.

An internal combustion engine cooling system according to claim 1 mixes the coolant flowed from an internal combustion engine and cooled while the same flows through a radiator, and the coolant from a bypass passage bypassing the radiator in a flow control valve, circulates the coolant by a water pump placed in an inlet or an outlet passage, and controls the temperature of the coolant flowing through the outlet passage on the basis of a desired coolant temperature set by a desired coolant temperature setting means for the coolant flowing through the outlet passage. The desired coolant temperature is adjusted according to the operating condition of the internal combustion engine, the traveling mode of the vehicle with the internal combustion engine and

environmental conditions. Thus, the desired coolant temperature can properly be adjusted in an narrow temperature range near a knock-limit temperature, knock can be prevented with a sufficient allowance, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be reduced.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 2 changes the desired coolant temperature for the internal combustion engine from the normal desired coolant temperature in accordance with uphill/downhill traveling mode as the operating condition of the internal combustion engine. In this manner, as the desired coolant temperature of coolant temperature for the internal combustion engine is properly set in accordance with uphill/downhill traveling mode as the operating condition of the internal combustion engine with a sufficient allowance from a knock-limit temperature, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 3 sets a desired coolant temperature lower than the normal desired coolant temperature corresponding to a flatland level when the vehicle is traveling in the uphill traveling mode as the operating condition of the internal combustion engine, since it is assumed that the load is continuously heavy and the coolant temperature will rise. In this manner, the desired coolant temperature for the internal combustion engine is properly set when the vehicle is traveling in the uphill traveling mode as the operating condition of the internal combustion engine and even if the desired coolant temperature is in an narrow temperature range near a knock-limit temperature. Accordingly, the occurrence of knock can be prevented, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal

combustion engine cooling system in claim 4 sets a desired coolant temperature higher than the normal desired coolant temperature corresponding to the flatland level when the vehicle is traveling in the downhill traveling mode as the operating condition of the internal combustion engine, since it is assumed that the load is continuously light and the coolant temperature will decrease. This further reduces friction resistance. In this manner, when the vehicle is traveling in the downhill traveling mode as the operating condition of the internal combustion engine and the desired coolant temperature for the internal combustion engine has a sufficient allowance from a knock-limit temperature, the desired coolant temperature is properly set to a higher temperature not to cause knock. Accordingly, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 5 changes the desired coolant temperature for the internal combustion engine from the normal desired coolant temperature in accordance with steady traveling/transient traveling state as the operating condition of the internal combustion engine. In this manner, as the desired coolant temperature of coolant temperature for the internal combustion engine is properly set in accordance with steady traveling/transient traveling state as the operating condition of the internal combustion engine with a sufficient allowance from a knock-limit temperature, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 6 sets a desired coolant temperature lower than the normal desired coolant temperature corresponding to the steady traveling state when the vehicle is in the transient traveling state as the operating condition of the internal combustion engine, since the load varies in a wide range and knock tends to occur. In this manner, the desired coolant temperature for

the internal combustion engine is properly set when the vehicle is traveling in the transient traveling state as the operating condition of the internal combustion engine and even if the desired coolant temperature is in a narrow temperature range near a knock-limit temperature. Accordingly, the occurrence of knock can be prevented, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 7 changes the desired coolant temperature for the internal combustion engine from the normal desired coolant temperature in accordance with high altitude/low altitude level as an ambient condition of the internal combustion engine. In this manner, as the desired coolant temperature for the internal combustion engine is changed in accordance with high altitude/low altitude level as the ambient condition of the internal combustion engine with a sufficient allowance from a knock-limit temperature, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 8 sets a desired coolant temperature lower than the normal desired coolant temperature corresponding to flatland level when the altitude is high as the ambient condition of the internal combustion engine, since atmospheric pressure is low and exhaust pressure is reduced and the knock tends to occur due to raise of charging efficiency. In this manner, the desired coolant temperature is properly set when the altitude is high as the ambient condition of the internal combustion engine and even if the desired coolant temperature is in a narrow temperature range near a knock-limit temperature. Accordingly, the occurrence of knock can be prevented, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal

combustion engine cooling system in claim 9 changes the desired coolant temperature for the internal combustion engine from the normal desired coolant temperature in accordance with humidity as the ambient condition of the internal combustion engine. In this manner, as the desired coolant temperature for the internal combustion engine is properly changed with a sufficient allowance from a knock-limit temperature in accordance with humidity as the ambient condition of the internal combustion engine, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 10 sets a desired coolant temperature for the internal combustion engine higher than the normal desired coolant temperature as humidity as the ambient condition of the internal combustion engine increases, since knock hardly occurs due to increased humidity of the atmosphere. In this manner, as the desired coolant temperature for the internal combustion engine is properly set with a sufficient allowance from a knock-limit temperature as humidity as the ambient condition of the internal combustion engine increases, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 11 changes the desired coolant temperature for the internal combustion engine from the normal desired coolant temperature in accordance with intake temperature state as the ambient condition of the internal combustion engine. In this manner, as the desired coolant temperature for the internal combustion engine is properly set with a sufficient allowance from a knock-limit temperature in accordance with intake temperature state as the ambient condition of the internal combustion engine, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal

combustion engine cooling system in claim 12 sets a desired coolant temperature for the internal combustion engine lower than the normal desired coolant temperature as intake temperature as the ambient condition of the internal combustion engine increases, since knock tends to occur. In this manner, the desired coolant temperature for the internal combustion engine is properly set even if it is in a narrow temperature range near a knock-limit temperature as intake temperature as the ambient condition of the internal combustion engine increases. Accordingly, the occurrence of knock can be prevented, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 13 controls the coolant temperature for a direct-injection type engine as the internal combustion engine with a flow control valve. At this time, the desired coolant temperature for the direct-injection type engine as the internal combustion engine is changed from the normal desired coolant temperature in accordance with combustion mode of the direct-injection type engine. In this manner, as the desired coolant temperature for the direct-injection type engine is changed with a sufficient allowance from a knock-limit temperature in accordance with combustion mode of the direct-injection type engine as the internal combustion engine, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 14 sets a desired coolant temperature for the direct-injection type engine as the internal combustion engine higher than the normal desired coolant temperature when the direct-injection type engine is in a stratified charge combustion mode, since friction and exhaust gas are reduced. In this manner, as the desired coolant temperature for the direct-injection type engine is properly set when the

direct-injection type engine as the internal combustion engine is in the stratified charge combustion mode, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 15 controls the coolant temperature for a lean-burn type engine as the internal combustion engine with a flow control valve. At this time, the desired coolant temperature for the lean-burn type engine as the internal combustion engine is changed from the normal desired coolant temperature in accordance with combustion mode of the lean-burn type engine. In this manner, as the desired coolant temperature for the lean-burn type engine is changed with a sufficient allowance from a knock-limit temperature in accordance with combustion mode of the lean-burn type engine as the internal combustion engine, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

The desired coolant temperature setting means in the internal combustion engine cooling system in claim 16 sets a desired coolant temperature for the lean-burn type engine as the internal combustion engine higher than the normal desired coolant temperature when the lean-burn type engine is in a lean-burn combustion mode since friction and exhaust gas are reduced. In this manner, as the desired coolant temperature for the lean-burn type engine is properly set when the lean-burn type engine as the internal combustion engine is in the lean-burn combustion mode, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

#### [Embodiment of the Invention]

The present invention will be described with reference to an embodiment.

#### (First Embodiment)

Fig. 1 is diagrammatic view of an internal combustion engine and

peripheral devices to which an internal engine cooling system according to the first embodiment of the present invention is applied.

Referring to Fig. 1, an internal combustion engine (hereinafter, referred to simply as "engine") 10 is connected to a radiator 20 for cooling engine cooling water (hereinafter, referred to as "coolant") by an inlet passage 11 and an outlet passage 12. The inlet passage 11 and the outlet passage 12 are connected by a bypass passage 13. A rotary flow control valve 30 is placed at the junction of the outlet passage 12 and the bypass passage 13. An electric water pump 35 is placed in a part, between the flow control valve 30 and the engine 10, of the outlet passage 12. A radiator fan 21 is disposed behind the radiator 20. A fan motor 22 drives the radiator fan 21 when necessary.

A potentiometer 31 is combined with the valve shaft, not shown, of the flow control valve 30 to measure the valve opening of the flow control valve 30. A first coolant temperature sensor 41 for measuring the temperature of the coolant flowing into the electric water pump 35, i.e., inlet coolant temperature, is placed in a part, between the flow control valve 30 and the electric motor 35, of the outlet passage 12. A second coolant temperature sensor 42 for measuring the temperature of the coolant flowing into the flow control valve 30 is placed near the flow control valve 30 connected to the bypass passage 13. A third coolant temperature sensor 43 for measuring the temperature of the coolant flowing into the flow control valve 30 is placed in a part, between the radiator 20 and the flow control valve 30, of the outlet passage 12. The engine 10 is provided with an engine-speed sensor 15 for measuring engine speed. A throttle valve 17 is placed in an intake pipe 16. A throttle-position sensor 18 measures the position of the throttle valve 17. An intake-pressure sensor 19 for measuring intake pressure, i.e., load, is disposed below the throttle valve 17.

The coolant for cooling the engine 10 flows along a route indicated by blank arrows in Fig. 1. The electric water pump 35 forces the coolant through the outlet passage 12 into the engine 10. The coolant circulated through the engine 10 flows through the inlet passage 11 into the radiator 20. The coolant

is cooled as it flows through the radiator 20, and then the thus cooled coolant is supplied through the outlet passage 12 into the engine 10 at a flow rate determined by the valve opening of the flow control valve 30. Part of the coolant flowing through the inlet passage 11 is returned through the bypass passage 13 into the engine 10 so that the coolant of a predetermined temperature is supplied into the engine 10.

An electronic control unit (ECU) 60 receives an intake-pressure signal provided by the intake-pressure sensor 19, an engine-speed signal provided by the engine-speed sensor 15, a valve-opening signal provided by the potentiometer 31, a first coolant temperature signal provided by the first coolant temperature sensor 41, a second coolant temperature signal provided by the second coolant temperature sensor 42, a third coolant temperature signal provided by the third coolant temperature sensor 43, a vehicle-speed signal provided by the vehicle-speed sensor 51, a gear-ratio signal provided by a gear-ratio sensor 52, an AT control signal provided by an AT controller 53, an atmospheric-pressure signal provided by an atmospheric-pressure sensor 54, a humidity signal provided by a humidity sensor 55, an intake temperature signal provided by an intake temperature sensor 56, and an ambient temperature signal provided by an ambient-temperature sensor 57.

The ECU 60 is an arithmetic/logic unit comprising a CPU 61, i.e., a generally known central processing unit capable of carrying out various arithmetic operations, a ROM 62 storing control programs and control maps, a RAM 63 for storing data, a backup RAM 64, an I/O circuit 65 and bus lines 66 connecting those components. The ECU 60 controls the flow control valve 30, the electric pump 35 and the electric motor 22 on the basis of the signals provided by the sensors.

A coolant temperature control routine to be carried out by the CPU 61 of the ECU 60 will be described with reference to a flow chart shown in Fig. 2. The valve opening of the flow control valve 30 is controlled to control coolant temperature. The CPU 61 repeats the coolant temperature control routine at a

predetermined period.

Referring to Fig. 2, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S101. The ECU 60 receives a vehicle-speed signal, provided by the vehicle-speed sensor 51, a gear-ratio signal provided by the gear-ratio sensor 52 or an AT control signal provided by the AT controller 53 as traveling-mode information, or an atmospheric-pressure signal provided by the atmospheric-pressure sensor 54, a humidity signal provided by the humidity sensor 55 or a intake-temperature sensor provided by the intake-temperature sensor 56 as an ambient-condition information in step S102.

Then, a desired coolant temperature is set according to the operating condition of the engine 10 and the raveling mode, or the ambient condition in step S103. Then, a query is made in step S103 to see if the coolant temperature at the inlet of the electric water pump 35, i.e., a coolant temperature of the coolant to be pumped into the engine 10, is within a predetermined range around the desired coolant temperature set in the step S103. If the response to the query made in step S104 is affirmative, i.e., if the coolant temperature is within the predetermined range around the desired coolant temperature, the routine goes to step S105. In step S105, the valve opening of the flow control valve 30 is kept unchanged, and then the routine is ended. If the response to the query made in step S104 is negative, i.e., the coolant temperature is outside the predetermined range around the desired coolant temperature, the routine goes to step S106. An optimum valve opening for adjusting the coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum value opening is given to the flow control value 30 in step S106, and then the routine is ended.

In this manner, the internal engine cooling system has: the radiator 20

which cools the coolant flowing from the engine 10 then lets out the coolant toward the engine 10; the flow control valve 30, placed in a confluence portion among the inlet passage 11 and outlet passage 12 as coolant passages connecting the engine 10 with the radiator 20, the bypass passage 13 which bypasses the coolant flowing from the engine 10 from the inlet passage 11, avoiding the radiator 20, to the outlet passage 12 on the outlet side of the radiator 20, the outlet passage 12 through the radiator 20 on the coolant outlet side, and the coolant outlet side through the bypass passage 13, to control the radiator flow amount of the coolant flowing through the radiator 20 and the bypass flow amount of the coolant flowing through the bypass passage 13; the electric pump 35 placed in a part of the inlet passage 11 or the outlet passage 12, to circulate the coolant flowing through the passages 11 and 12; the desired coolant temperature setting means, achieved by the ECU 60 to set a desired coolant temperature (normal desired coolant temperature) of the coolant flowing through the outlet passage 12; and the coolant temperature control means achieved by the potentiometer 31 to control the coolant temperature in the outlet passage 12 based on the desired coolant temperature set by the desired coolant temperature setting means, the various sensor signals from the coolant temperature sensors 41, 42 and 43 and the ECU 60. The desired coolant temperature setting means changes the desired coolant temperature of the coolant in accordance with operating condition, running condition, ambient condition of the engine 10.

The cooled coolant flowed through the inlet passage 11 and cooled by the radiator 20 and the uncooled coolant flowed through the bypass passage 13 bypassing the radiator are mixed in the flow control valve 30 controlled by the ECU 60 on the basis of the signals provided by the potentiometer 31, the coolant-temperature sensors 41, 42 and 43, and the mixed coolant is pumped into the engine 10 by the electric water pump 35 placed in the outlet passage 12. Since the desired coolant temperature is variable according to the operating

condition of the engine 10, the traveling mode and the ambient condition, the engine 10 is able to operate efficiently and fuel consumption can be reduced.

(Second Embodiment)

A traveling-mode deciding routine shown in Fig. 3 and a coolant temperature control routine shown in Fig. 4 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a second embodiment according to the present invention will be described. The CPU 61 repeats the traveling-mode deciding routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 3, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and a vehicle-speed signal provided by the vehicle-speed sensor 51 or an AT control signal provided by an AT controller 53 in step S201. In step S202, a traveling mode, i.e., an uphill traveling mode, a downhill traveling mode or a level traveling mode, is decided from maps stored in the ROM 62 by using the engine-speed signal, the intake-pressure signal and the gear-ratio signal received in step S201 as parameters. The traveling mode of the vehicle may be decided on the basis of information provided by the AT controller, i.e., traveling-mode information. Then, an uphill counter, a downhill counter or a level counter is incremented every predetermined time in step S203. A query is made in step S204 to see if the count of the uphill counter while the vehicle is in the uphill traveling mode is greater than a threshold. If the response to the query made in step S204 is affirmative, i.e., if the count of the uphill counter is greater than the threshold, it is decided that the vehicle is in the uphill traveling mode in step S205.

If the response to the query made in step S204 is negative, i.e., if the count of the uphill counter is not greater than the threshold, a query is made in step S206 to see if the count of the downhill counter when the vehicle is in the downhill traveling mode is greater than a threshold. If the response to the

query made in step S206 is affirmative, i.e., the count of the downhill counter is greater than the threshold, it is decided in step S207 that the vehicle is in the uphill traveling mode and the routine is ended. If the response to the query made in step S206 is negative, i.e., if the count of the downhill counter is not greater than the threshold, it is decided in step S208 that the vehicle is in the flat traveling mode and then the routine is ended.

Referring to Fig. 4, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S211. Then, a query is made in step S212 to see if the traveling-mode deciding routine shown in Fig. 3 decided that the vehicle is in the uphill traveling mode. If the response to the query made in step S212 is affirmative, i.e., if the vehicle is in the uphill traveling mode, a desired coolant temperature for the uphill traveling mode is set in step S213. The desired coolant temperature for the uphill traveling mode is lower than a normal desired coolant temperature for the level traveling mode because it is expected that the continuous load on the engine 10 and coolant temperature rise in the uphill traveling mode are greater than those in the level traveling mode.

If the response to the query made in step S212 is negative, i.e., if the vehicle is not in the uphill traveling mode, a query is made in step S214 to see if the traveling-mode deciding routine shown in Fig. 3 decided that the vehicle is in the downhill traveling mode. If the response to the query made in step S214 is affirmative, i.e., if the vehicle is in the downhill traveling mode, a desired coolant temperature for the downhill traveling mode is determined in step S215. The desired coolant temperature for the downhill traveling mode including a deceleration mode is higher than the normal desired coolant temperature for the level traveling mode because it is expected that the continuous load on the engine 10 and coolant temperature rise in the downhill traveling mode are

smaller than those in the level traveling mode. The higher desired coolant temperature is effective in further reducing frictional resistance. If the response to the query made in step S214 is negative, i.e., if the vehicle is not in the downhill traveling mode, the normal desired coolant temperature for the level traveling mode is determined in step S216.

A query is made in step S217 to see if inlet coolant temperature at the inlet of the electric water pump 35 is within a predetermined range around the desired coolant temperature determined in step S213, 215 or 216. If the response to the query made in step S217 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S218, and then the routine is ended. If the response to the query made in step S217 is negative, i.e., the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening to adjust the inlet coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum valve opening is given to the flow control valve 30 in step S219, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the ECU 60 changes the desired coolant temperature from the normal desired coolant temperature corresponding to a flatland level in accordance with uphill/downhill traveling mode as the operating condition. That is, the coolant temperature for the engine 10 is controlled by the valve opening of the flow control valve 30 in accordance with the various sensor signals from the potentiometer 31, the coolant temperature sensors 41, 42 and 43 and the ECU 60. At this time, the desired coolant temperature for the engine 10 is changed from the normal desired coolant temperature corresponding to the flatland level in accordance with uphill/downhill traveling mode as the operating condition of

the engine 10. Accordingly, as the desired coolant temperature for the engine 10 is changed with a sufficient allowance from a knock-limit temperature in accordance with uphill/downhill traveling mode as the operating condition of the engine 10, the engine is kept at its most efficient temperature, friction is further reduced, and fuel consumption can be improved.

(Third Embodiment)

A steady/transient traveling state deciding routine shown in Fig. 5 and a coolant temperature control routine shown in Fig. 6 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a third embodiment according to the present invention will be described. The CPU 61 repeats the steady/transient traveling state deciding routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 5, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and a vehicle-speed signal provided by the vehicle-speed sensor 51 or an AT control signal provided by the AT controller 53 in step S301. Then, in step S302, an integrated change of loads (intake pressure, throttle opening and amount of intake air) on the engine 10 or an integrated change of engine speed is calculated for steady/transient traveling state decision. A query is made in step S303 to see if the integrated change calculated in step S302 is not smaller than a predetermined value. If the response to the query made in step S303 is affirmative, i.e., if the integrated change is not smaller than the predetermined value, it is decided in step S304 that the vehicle is traveling in a transient traveling state, and then the routine is ended. If the response to the query made in step S303 is negative, i.e., if the integrated change is less than the predetermined value, it is decided in step S305 that the vehicle is traveling in a steady traveling state, and then the routine is ended.

Referring to Fig. 6, the ECU 60 receives an engine-speed signal, i.e., a

signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S311. Then, a query is made in step S312 to see if the steady/transient traveling state deciding routine shown in Fig. 5 decided that the vehicle is in the steady traveling state.

If the response to the query made in step S312 is affirmative, i.e., if the vehicle is in the steady traveling state, a normal desired coolant temperature for the steady traveling state is set in step S313. If the response to the query made in step S312 is negative, i.e., if the vehicle is in the transient traveling state, a desired coolant temperature for the transient traveling state is set in step S314. The desired coolant temperature for the transient traveling state is lower than that for the steady traveling state because load varies in a wide range and knock tends to occur in the transient traveling state. Then, a query is made in step S315 to see if the inlet coolant temperature at the inlet of the electric water pump 35 is within a predetermined range around the desired coolant temperature set in step S313 or 314. If the response to the query made in step S315 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S316, and then the routine is ended. If the response to the query made in step S315 is negative, i.e., if the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening to adjust the inlet coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum valve opening is given to the flow control valve 30 in step S317, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the

ECU 60 changes the desired coolant temperature from the normal desired coolant temperature in accordance with steady traveling/transient traveling state as the operating condition. That is, the coolant temperature for the engine 10 is controlled by the valve opening of the flow control valve 30 in accordance with the various sensor signals from the potentiometer 31, the coolant temperature sensors 41, 42 and 43 and the ECU 60. At this time, the desired coolant temperature for the engine 10 is changed from the normal desired coolant temperature in accordance with steady traveling/transient traveling state as the operating condition of the engine 10. Accordingly, as the desired coolant temperature for the engine 10 is changed with a sufficient allowance from a knock-limit temperature in accordance with steady traveling/transient traveling state as the operating condition of the engine 10, the engine is kept at its most efficient temperature and fuel consumption can be improved.

(Fourth Embodiment)

An altitude-level determining routine shown in Fig. 7 and a coolant temperature control routine shown in Fig. 8 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a fourth embodiment according to the present invention will be described. The CPU 61 repeats the altitude-level determining routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 7, the ECU 60 receives an atmospheric-pressure signal provided by the atmospheric-pressure sensor 54 or an engine-speed signal provided by the engine-speed sensor 15, an intake-pressure signal provided by the intake-pressure sensor 19, and a throttle-position signal provided by the throttle-position sensor 18 in step S401. The atmospheric pressure is represented by the atmospheric-pressure signal provided by the atmospheric-pressure sensor 54 when the internal combustion engine cooling system is provided with the atmospheric pressure sensor 54. The atmospheric pressure can be estimated from intake pressure at the start of the engine 10 or

from intake pressure in a state where engine speed is not higher than a predetermined level and throttle opening is not smaller than a predetermined throttle opening if the internal combustion engine cooling system is not provided with the atmospheric-pressure sensor 54. A query is made in step S402 to see if the atmospheric pressure measured in step S401 is not higher than a predetermined pressure. If the response to the query made in step S402 is affirmative, i.e., if the atmospheric pressure is not higher than the predetermined pressure, it is decided that the vehicle is at a high altitude in step S403, and then the routine is ended. If the response to the query made in step S402 is negative, i.e., if the atmospheric pressure is higher than the predetermined pressure, it is decided that the vehicle is at a low altitude in step S404 and then the routine is ended.

Referring to Fig. 8, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S411. Then, a query is made in step S412 to see if the altitude-level determining routine decided that the vehicle is at a high altitude. If the response to the query made in step S412 is affirmative, i.e., if the vehicle is at a high altitude, a desired coolant temperature for high altitude is determined in step S413. The atmospheric pressure is low, exhaust pressure is low and the charging efficiency of the engine 10 is high at high altitudes. Consequently, the possibility of knock at high altitudes is higher than that at low altitudes. Therefore, the desired coolant temperature for high altitudes is lower than that for low altitudes. If the response to the query made in step S412 is negative, i.e., if the vehicle is at a low altitude, a normal desired coolant temperature for a low altitude level is determined in step S414.

Then, a query is made in step S415 to see if inlet coolant temperature at the inlet of the electric water pump 35 is in a predetermined range around the

desired coolant temperature set in step S413 or 414. If the response to the query made in step S415 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S416, and then the routine is ended. If the response to the query made in step S415 is negative, i.e., if the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening to adjust the inlet coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum valve opening is given to the flow control valve 30 in step S417, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the ECU 60 changes the desired coolant temperature from the normal desired coolant temperature in accordance with high altitude/low altitude level as an ambient condition. That is, the coolant temperature for the engine 10 is controlled by the valve opening of the flow control valve 30 in accordance with the various sensor signals from the potentiometer 31, the coolant temperature sensors 41, 42 and 43 and the ECU 60. At this time, the desired coolant temperature for the engine 10 is changed from the normal desired coolant temperature in accordance with high altitude/low altitude level as the ambient condition of the engine 10. Accordingly, as the desired coolant temperature for the engine 10 is changed with a sufficient allowance from a knock-limit temperature in accordance with high altitude/low altitude level as the ambient condition of the engine 10, the engine is kept at its most efficient temperature and fuel consumption can be improved.

(Fifth Embodiment)

An atmospheric pressure measuring routine shown in Fig. 9 and a coolant temperature control routine shown in Fig. 10 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a

fifth embodiment according to the present invention will be described. The CPU 61 repeats the atmospheric pressure measuring routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 9, the ECU 60 receives an atmospheric-pressure signal provided by the atmospheric-pressure sensor 54 or an engine-speed signal provided by the engine-speed sensor 15, i.e., information about atmospheric pressure, an intake-pressure signal provided by the intake-pressure sensor 19 and a throttle-position signal provided by the throttle-position sensor 18 in step S501, and then the routine is ended.

Referring to Fig. 10, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S511. A desired coolant temperature is set in step S512 according to the atmospheric pressure measured by the atmospheric pressure measuring routine shown in Fig. 9. The desired coolant temperature for low atmospheric pressures is lower than the normal desired coolant temperature for high atmospheric pressures because knock tends to occur at high altitudes where the atmospheric pressure is low.

A query is made in step S513 to see if inlet coolant temperature at the inlet of the electric water pump 35 is within a predetermined range around the desired coolant temperature set in step S512. If the response to the query made in step S512 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S514, and then the routine is ended. If the response to the query made in step S512 is negative, i.e., if the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening for adjusting the coolant temperature to the desired coolant temperature is calculated and a valve

opening signal representing the calculated optimum value opening is given to the flow control valve 30 in step S515, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the ECU 60 decreases the desired coolant temperature below the normal desired coolant temperature as the altitude as the ambient condition becomes higher.  
(Sixth Embodiment)

A humidity-level determining routine shown in Fig. 11 and a coolant temperature control routine shown in Fig. 12 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a sixth embodiment according to the present invention will be described. The CPU 61 repeats the atmospheric pressure measuring routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 11, the ECU 60 receives a humidity signal provided by the humidity sensor 55 in step S601. A query is made in step S602 to see if a humidity represented by the humidity signal received in step S601 is not higher than a predetermined value. If the response to the query made in step S602 is affirmative, i.e., if the humidity is not higher than the predetermined value, it is decided in step S603 that the humidity of the atmosphere is low, and then the routine is ended. If the response to the query made in step S602 is negative, i.e., if the humidity is higher than the predetermined value, it is decided in step S604 that the humidity of the atmosphere is high, and then the routine is ended.

Referring to Fig. 12, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S611. A query is made in step S612 to see if the humidity-level determining routine shown in Fig. 11 decided that the humidity is high. If the response to the query made in step S612 is affirmative, i.e., if the

humidity is high, a desired coolant temperature for the high humidity determined in step S604 is determined in step S613. It is expected that the atmosphere contains much moisture and knock does not occur easily when the humidity is high. Therefore, the desired coolant temperature for high humidities is higher than a normal desired coolant temperature for low humidities. If the response to the query made in step S612 is negative, i.e., if the humidity is low, the normal desired coolant temperature for low humidities is set in step S614.

A query is made in step S615 to see if inlet coolant temperature at the inlet of the electric water pump 35 is within a predetermined range around the desired coolant temperature set in step S613 or 614. If the response to the query made in step S615 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S615, and then the routine is ended. If the response to the query made in step S615 is negative, i.e., if the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening for adjusting the coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum value opening is given to the flow control valve 30 in step S617, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the ECU 60 changes the desired coolant temperature from the normal desired coolant temperature in accordance with humidity as an ambient condition. That is, the coolant temperature for the engine 10 is controlled by the valve opening of the flow control valve 30 in accordance with the various sensor signals from the potentiometer 31, the coolant temperature sensors 41, 42 and 43 and the ECU 60. At this time, the desired coolant temperature for the engine 10 is properly changed from the normal desired coolant temperature in accordance with humidity as the ambient condition of the engine 10. Accordingly, as the desired

coolant temperature for the engine 10 is changed with a sufficient allowance from a knock-limit temperature in accordance with humidity as the ambient condition of the engine 10, the engine is kept at its most efficient temperature and fuel consumption can be improved.

(Seventh Embodiment)

A humidity measuring routine shown in Fig. 13 and a coolant temperature control routine shown in Fig. 14 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a seventh embodiment according to the present invention will be described. The CPU 61 repeats the humidity measuring routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 13, the humidity sensor 55 measures the humidity of the atmosphere in step S701, and then the humidity measuring routine is ended.

Referring to Fig. 14, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S711. Then, a desired coolant temperature is determined in step S712 on the basis of the humidity determined by the humidity measuring routine in Fig. 13. It is expected that the atmosphere contains much moisture and knock does not occur easily when the humidity is high. Therefore, the desired coolant temperature for high humidities is higher than the normal desired coolant temperature for low humidities.

Then, a query is made in step S713 to see if the inlet coolant temperature is within a predetermined range around the desired coolant temperature set in step S712. If the response to the query made in step S713 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S714, and then the routine is ended.

If the response to the query made in step S713 is negative, i.e., if the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening for adjusting the coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum value opening is given to the flow control valve 30 in step S715, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the ECU 60 increases a desired coolant temperature beyond the normal desired coolant temperature as humidity as an ambient condition increases. In this manner, as the desired coolant temperature for the engine 10 is properly set with a sufficient allowance from a knock-limit temperature as humidity as the ambient condition of the engine 10 increases, the internal combustion engine is kept at its most efficient temperature and fuel consumption can be improved.

(Eighth Embodiment)

An intake air temperature level determining routine shown in Fig. 15 and a flow chart of a coolant temperature control routine shown in Fig. 16 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in an eighth embodiment according to the present invention will be described. The CPU 61 repeats the humidity measuring routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 15, the ECU 60 receives an intake-temperature signal provided by the intake-temperature sensor 56 or an ambient-temperature signal or an estimated-ambient-temperature signal provided by the ambient-temperature sensor 57, i.e., a signal indicating information about intake temperature in step S801. Then, a query is made in step S802 to see if the intake temperature is not lower than a predetermined value. If the response to the query made in step S802 is affirmative, i.e., if the intake temperature is not lower than the predetermined value, it is decided in step S803 that the intake temperature is at a high level, and then the routine is ended. If the response to

the query made in step S802 is negative, i.e., if the intake temperature is below the predetermined value, it is decided in step S804 that the intake temperature is at a low level, and then the routine is ended.

Referring to Fig. 16, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S811. Then, a query is made in step S812 to see if the intake air temperature level determining routine decided that the intake temperature is at a high level. If the response to the query made in step S812 is affirmative, i.e., the intake temperature is at a high level, a desired coolant temperature for high intake temperatures is set in step S813. The desired coolant temperature for high intake temperatures is lower than that for low intake temperatures because knock tends to occur at high intake temperatures. If the response to the query made in step S812 is negative, i.e., the intake temperature is at a low level, a desired coolant temperature for low intake temperatures is set in step S814. The desired coolant temperature for low intake temperatures is higher than that for high intake temperatures because knock does not occur easily at low intake temperatures.

A query is made in step S815 to see if inlet coolant temperature is within a predetermined range around the desired coolant temperature set in 813 or 814. If the response to the query in step S815 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S816, and then the routine is ended. If the response to the query in step S815 is negative, i.e., if the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening for adjusting the coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum

value opening is given to the flow control value 30 in step S817, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the ECU 60 changes the desired coolant temperature from the normal desired coolant temperature in accordance with intake temperature state as an ambient condition. That is, the coolant temperature for the engine 10 is controlled by the valve opening of the flow control valve 30 in accordance with the various sensor signals from the potentiometer 31, the coolant temperature sensors 41, 42 and 43 and the ECU 60. At this time, the desired coolant temperature for the engine 10 is changed from the normal desired coolant temperature in accordance with intake temperature state as the ambient condition of the engine 10. Accordingly, as the desired coolant temperature for the engine 10 is properly changed with a sufficient allowance from a knock-limit temperature in accordance with intake temperature state as the ambient condition of the engine 10, the engine is kept at its most efficient temperature and fuel consumption can be improved.

#### (Ninth Embodiment)

An intake air temperature measuring routine shown in Fig. 17 and a coolant temperature control routine shown in Fig. 18 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a ninth embodiment according to the present invention will be described. The CPU 61 repeats the humidity measuring routine and the coolant temperature control routine at a predetermined period.

Referring to Fig. 17, the ECU 60 receives an intake-temperature signal provided by the intake-temperature sensor 56 in step S901, and then the routine is ended.

Referring to Fig. 18, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the

engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S911. Then, a desired coolant temperature is determined in step S912 on the basis of the intake temperature measured by the intake-temperature measuring routine shown in Fig. 17. The desired coolant temperature for high intake temperatures is lower than a normal desired coolant temperature because knock tends to occur when the intake temperature is high.

A query is made in step S913 to see if inlet coolant temperature is within a predetermined range around the desired coolant temperature set in step S912. If the response to the query made in step S913 is affirmative, i.e., the intake temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S914, and then the routine is ended. If the response to the query made in step S913 is negative, i.e., if the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening for adjusting the coolant temperature to the desired coolant temperature is calculated and valve opening of the flow control valve 30 is adjusted to the calculated optimum valve opening in step S915, and then a valve opening signal representing the calculated optimum value opening is given to the flow control valve 30.

In this manner, in the internal engine cooling system of the present embodiment, the desired coolant temperature setting means achieved with the ECU 60 decreases the desired coolant temperature below the normal desired coolant temperature as intake temperature as an ambient condition increases. In this manner, the desired coolant temperature for the engine 10 is properly set even if it is in a narrow temperature range near a knock-limit temperature as humidity as the ambient condition of the engine 10 increases. Accordingly, the occurrence of knock can be prevented, the internal combustion engine is kept at

its most efficient temperature and fuel consumption can be improved.

(Tenth Embodiment)

A coolant temperature control routine shown in Fig. 19 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in a tenth embodiment according to the present invention, following the determination of the mode of combustion in the engine 10 will be described. The CPU 61 repeats the humidity measuring routine and the coolant temperature control routine at a predetermined period. The engine 10 is assumed to be a direct-injection engine.

Referring to Fig. 19, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S1001. A query is made in step S1002 to see if the engine 10 is operating in a stratified charge combustion mode. If the response to the query made in step S1002 is affirmative, i.e., if the engine 10 is operating in the stratified charge combustion mode, a desired coolant temperature for the stratified charge combustion mode is set in step S1003. The desired coolant temperature for the stratified charge combustion mode is higher than an ordinary desired coolant temperature for a uniform charge combustion mode. If the response to the query made in step S1002 is negative, i.e., if the engine 10 is operating in the uniform charge combustion mode, a desired coolant temperature for the uniform charge combustion mode is set in step S1004.

A query is made in step S1005 to see if inlet coolant temperature at the inlet of the electric water pump 35 is within a predetermined range around the desired coolant temperature determined in step S1003 or 1004. If the response to the query made in step S1005 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant

temperature, the valve opening of the flow control valve 30 is kept unchanged in step S1006, and then the routine is ended. If the response to the query made in step S1005 is negative, i.e., the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening to adjust the inlet coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum value opening is given to the flow control valve 30 in step S1007, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, in a case where the engine 10 is a direct-injection type engine, the desired coolant temperature setting means achieved with the ECU 60 changes the desired coolant temperature from the normal desired coolant temperature in accordance with combustion mode. That is, the coolant temperature for the engine 10 is controlled by the valve opening of the flow control valve 30 in accordance with the various sensor signals from the potentiometer 31, the coolant temperature sensors 41, 42 and 43 and the ECU 60. At this time, the desired coolant temperature for the direct-injection type engine as the engine 10 is changed from the normal desired coolant temperature in accordance with combustion mode of the direct-injection type engine. Accordingly, as the desired coolant temperature for the direct-injection type engine is properly changed with a sufficient allowance from a knock-limit temperature in accordance with combustion mode of the direct-injection type engine as the engine 10, the engine is kept at its most efficient temperature and fuel consumption can be improved.

Further, in the internal engine cooling system of the present embodiment, when the direct-injection type engine as the engine 10 is in a stratified charge combustion mode, the desired coolant temperature setting means achieved with the ECU 60 sets a desired coolant temperature higher than the normal desired coolant temperature in a homogeneous combustion state. That is, when the

direct-injection type engine is in a stratified charge combustion mode, a desired coolant temperature for the direct-injection type engine as the engine 10 higher than the normal desired coolant temperature is set since friction and exhaust gas are reduced. Accordingly, as the desired coolant temperature for the direct-injection type engine is properly set when the direct-injection engine as the engine 10 is in the stratified charge combustion mode, the internal combustion engine is kept at its most efficient temperature, fuel consumption can be improved, and exhaust gas can be reduced.  
(Eleventh Embodiment)

A coolant temperature control routine shown in Fig. 20 to be carried out by a CPU 61 included in an ECU 60 employed in an internal engine cooling system in an eleventh embodiment according to the present invention, following the determination of the mode of combustion in the engine 10 will be described. The CPU 61 repeats the humidity measuring routine and the coolant temperature control routine at a predetermined period. The engine 10 is assumed to be a lean-burn engine.

Referring to Fig. 20, the ECU 60 receives an engine-speed signal, i.e., a signal indicating the operating condition of the engine 10, provided by the engine-speed sensor 15, an intake-pressure signal, i.e., a signal indicating load on the engine 10, provided by the intake-pressure sensor 19, and first, second and third coolant temperature signals provided by the coolant temperature sensors 41, 42 and 43 in step S1101. A query is made in step S1102 to see if the engine 10 is operating in a lean-burn mode. If the response to the query made in step S1102 is affirmative, i.e., if the engine 10 is operating in the lean-burn mode, a desired coolant temperature for the lean-burn mode is set in step S1103. The desired coolant temperature for the lean-burn mode is higher than an ordinary desired coolant temperature for a stoichiometric combustion mode. If the response to the query made in step S1102 is negative, i.e., if the engine 10 is operating in the stoichiometric combustion mode, a desired coolant temperature for the stoichiometric combustion mode is set in step S1104.

A query is made in step S1105 to see if inlet coolant temperature is within a predetermined range around the desired coolant temperature determined in step S1103 or 1104. If the response to the query made in step S1105 is affirmative, i.e., if the inlet coolant temperature is within the predetermined range around the desired coolant temperature, the valve opening of the flow control valve 30 is kept unchanged in step S1106, and then the routine is ended. If the response to the query made in step S1005 is negative, i.e., the inlet coolant temperature is outside the predetermined range around the desired coolant temperature, an optimum valve opening to adjust the inlet coolant temperature to the desired coolant temperature is calculated and a valve opening signal representing the calculated optimum valve opening is given to the flow control valve 30 in step S1107, and then the routine is ended.

In this manner, in the internal engine cooling system of the present embodiment, in a case where the engine 10 is a lean-burn type engine, the desired coolant temperature setting means achieved with the ECU 60 changes the desired coolant temperature from the normal desired coolant temperature in accordance with combustion mode. That is, the coolant temperature for the engine 10 is controlled by the valve opening of the flow control valve 30 in accordance with the various sensor signals from the potentiometer 31, the coolant temperature sensors 41, 42 and 43 and the ECU 60. At this time, the desired coolant temperature for the lean-burn type engine as the engine 10 is changed from the normal desired coolant temperature in accordance with combustion mode of the lean-burn type engine. Accordingly, as the desired coolant temperature for the lean-burn type engine is properly changed in accordance with combustion mode of the lean-burn type engine as the engine 10, the engine is kept at its most efficient temperature and fuel consumption can be improved.

Further, in the internal engine cooling system of the present embodiment, when the lean-burn type engine as the engine 10 is in a lean-burn combustion

mode, the desired coolant temperature setting means achieved with the ECU 60 sets a desired coolant temperature higher than the normal desired coolant temperature in a stoichiometric combustion mode. That is, when the lean-burn type engine is in a lean-burn combustion mode, a desired coolant temperature for the lean-burn type engine as the engine 10 higher than the normal desired coolant temperature is set since friction and exhaust gas are reduced. Accordingly, as the desired coolant temperature for the lean-burn type engine is properly set when the lean-burn type engine as the engine 10 is in the lean-burn combustion mode, the internal combustion engine is kept at its most efficient temperature, fuel consumption can be improved, and exhaust gas can be reduced.

[Brief Description of the Drawings]

Fig. 1 is diagrammatic view of an internal combustion engine and peripheral devices to which internal engine cooling systems in first to eleventh embodiments according to the present invention are applied;

Fig. 2 is a flow chart of a coolant temperature control routine to be carried out by a CPU included in an electronic control unit (abbreviated to "ECU") employed in an internal engine cooling system in the first embodiment;

Fig. 3 is a flow chart of a traveling mode deciding routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the second embodiment;

Fig. 4 is a flow chart of a coolant temperature control routine to be carried out according to the decision of a traveling mode;

Fig. 5 is a flow chart of a steady/transient traveling state deciding routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the third embodiment;

Fig. 6 is a flow chart of a coolant temperature control routine to be carried out according to the decision made by the steady/stationary traveling state deciding routine;

Fig. 7 is a flow chart of an altitude-level determining routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the fourth embodiment;

Fig. 8 is a flow chart of a coolant temperature control routine to be carried out according to an altitude level determined by the altitude-level determining routine shown in Fig. 7;

Fig. 9 is a flow chart of an atmospheric pressure measuring routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the fifth embodiment;

Fig. 10 is a flow chart of a coolant temperature control routine to be carried out according to the atmospheric pressure measured by the atmospheric pressure measuring routine shown in Fig. 9;

Fig. 11 is a flow chart of a humidity-level determining routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the sixth embodiment;

Fig. 12 is a flow chart of a coolant temperature control routine to be carried out according to a humidity level determined by the humidity-level determining routine shown in Fig. 11;

Fig. 13 is a flow chart of a humidity measuring routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the seventh embodiment;

Fig. 14 is a flow chart of a coolant temperature control routine to be carried out according to humidity information provided by the humidity measuring routine shown in Fig. 13;

Fig. 15 is a flow chart of an intake air temperature level determining routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the eighth embodiment;

Fig. 16 is a flow chart of a coolant temperature control routine to be carried out according to a decision made by the intake air temperature level determining routine shown in Fig. 15;

Fig. 17 is a flow chart of an intake air temperature measuring routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the ninth embodiment;

Fig. 18 is a flow chart of a coolant temperature control routine to be carried out according to information provided by the intake air temperature measuring routine shown in Fig. 17;

Fig. 19 is a flow chart of a coolant temperature control routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the tenth embodiment following the determination of the mode of combustion in a direct-injection engine;

Fig. 20 is a flow chart of a coolant temperature control routine to be carried out by a CPU included in an ECU employed in an internal engine cooling system in the eleventh embodiment following the determination of the mode of combustion in a lean-burn engine;;

[Explanation of Reference Numerals]

10	engine
11	inlet passage
12	outlet passage
13	bypass passage
20	radiator
30	flow control valve
31	potentiometer
41,42,43	coolant temperature sensor
60	ECU (Electronic Control Unit)

[Name of the Document]      Abstract Sheet

[Abstract]

[Object]    To keep an internal combustion engine at its most efficient temperature and improve fuel consumption by adjusting coolant temperature to cool the internal combustion engine in accordance with various conditions.

[Solution]      A part of coolant discharged from an internal combustion engine 10 and flowed through and cooled by a radiator 20, and the rest of the coolant flowed through a bypass passage 13 bypassing the radiator 20 are mixed in a flow control valve 30 controlled by ECU 60 on the basis of signals provided by sensors including a potentiometer 31 and coolant temperature sensors 41, 42, 43 and are circulated by an electric pump 35 to control the coolant temperature for the internal combustion engine 10. A desired coolant temperature of the coolant flowing into the internal combustion engine 10 is changed according to the operating condition of the internal combustion engine 10, the traveling condition of a vehicle mounted with the internal combustion engine 10 and the ambient condition. Thus, the temperature of the coolant flowing into the internal combustion engine 10 is changed properly so that frictional resistance in the internal combustion engine 10 and exhaust gas may be reduced and the internal combustion engine 10 may be kept at its most efficient temperature near a knock-limit temperature, and knock can be prevented with a sufficient allowance.

[Selected Figure]      Fig. 1

## Drawings

Fig. 1

- 10 engine
- 11 inlet passage
- 12 outlet passage
- 13 bypass passage
- 20 radiator
- 30 flow control valve
- 31 potentiometer
- 35 electric pump
- 41, 42, 43 coolant temperature sensor
- 51 vehicle-speed sensor
- 52 gear-ratio sensor
- 53 AT controller
- 54 atmospheric-pressure sensor
- 55 humidity sensor
- 56 intake-temperature sensor
- 57 ambient-temperature sensor

Fig. 2

S101

read engine operating condition (engine speed and load) and respective coolant temperatures

S102

read traveling condition (vehicle speed, gear ratio or AT controller information) or ambient condition (atmospheric pressure, humidity or intake temperature)

S103

set desired coolant temperature corresponding to engine operating condition and traveling mode or ambient condition

S104

coolant temperature at inlet of electric water pump within predetermined range?

S105

keep valve opening unchanged

S106

calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 3

S201

read traveling condition (engine speed, load, vehicle speed and gear ratio, or AT controller information)

S202 decision of traveling mode

吸気圧 intake pressure

登坂領域 uphill traveling mode

平地領域 level traveling mode

降坂領域 downhill traveling mode

機関回転速度 engine speed

1速 1st speed

2速 2nd speed

3速 3rd speed

S203 increment uphill counter, downhill counter or level counter by predetermined time

S204 uphill counter  $\geq$  threshold?

S205 decide vehicle is in uphill traveling mode

S206 downhill counter  $\geq$  threshold?

S207 decide vehicle is in downhill traveling mode

S208 decide vehicle is in level traveling mode

Fig. 4

S211 read engine operating condition (engine speed and load) and respective coolant temperatures

S212 uphill traveling mode?

S213 set desired coolant temperature for uphill traveling mode

S214 downhill traveling mode?

S215 set desired coolant temperature for downhill traveling mode

S216 set desired coolant temperature for level traveling mode

S217 coolant temperature at inlet of electric water pump within predetermined range?

S218 keep valve opening unchanged

S219 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 5

S301 read traveling condition (engine speed, load, vehicle speed and gear ratio, or AT controller information)

S302 calculate integrated change of load (intake pressure, throttle opening and intake air amount) or integrated change of engine speed

S303 integrated change  $\geq$  threshold?

S304 decide vehicle is traveling in transient traveling state

S305

decide vehicle is traveling in steady traveling state

Fig. 6

S311 read engine operating condition (engine speed and load) and respective coolant temperatures

S312 steady traveling state ?

S313 set desired coolant temperature for steady traveling state

S314 set desired coolant temperature for transient traveling state

S315 coolant temperature at inlet of electric water pump within predetermined range?

S316 keep valve opening unchanged

S317 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 7

S401

read atmospheric-pressure information (atmospheric pressure or engine speed, intake pressure, throttle opening, etc.)

S402 atmospheric pressure  $\leq$  threshold?

S403 decide vehicle is at high altitude

S404 decide vehicle is at low altitude

Fig. 8

S411 read engine operating condition (engine speed and load) and respective coolant temperatures

S412 at high altitude ?

S413 set desired coolant temperature for high altitude

S414 set desired coolant temperature for low altitude

S415 coolant temperature at inlet of electric water pump within predetermined range?

S416 keep valve opening unchanged

S417 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 9

S501 read atmospheric-pressure information (atmospheric pressure or engine speed, intake pressure, throttle opening, etc.)

Fig. 10

S511 read engine operating condition (engine speed and load) and respective coolant temperatures

S512 set desired coolant temperature for atmospheric pressure

S513 coolant temperature at inlet of electric water pump within predetermined range?

S514 keep valve opening unchanged

S515 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 11

- S601 read humidity information
- S602 humidity  $\leq$  threshold?
- S603 decide humidity of atmosphere is low
- S604 decide humidity of atmosphere is high

Fig. 12

S611 read engine operating condition (engine speed and load) and respective coolant temperatures

S612 humidity is high?

S613 set desired coolant temperature for high humidity

S614 set desired coolant temperature for low humidity

S615 coolant temperature at inlet of electric water pump within predetermined range?

S616 keep valve opening unchanged

S617 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 13

S701 read humidity information

Fig. 14

S711 read engine operating condition (engine speed and load) and respective coolant temperatures

S712 set desired coolant temperature based on humidity information

S713 coolant temperature at inlet of electric water pump within predetermined range?

S714 keep valve opening unchanged

S715 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 15

S801

read intake-temperature information (intake temperature or ambient temperature or estimated ambient temperature)

S802 intake temperature  $\geq$  threshold?

S803 decide intake temperature is at high level

S804 decide intake temperature is at low level

Fig. 16

S811

read engine operating condition (engine speed and load) and respective coolant temperatures

S812 intake temperature is at high level?

S813 set desired coolant temperature for high intake temperature

S814 set desired coolant temperature for low intake temperature

S815 coolant temperature at inlet of electric water pump within predetermined range?

S816 keep valve opening unchanged

S817 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 17

S901 read intake-temperature information

Fig. 18

S911 read engine operating condition (engine speed and load) and respective coolant temperatures

S912 set desired coolant temperature based on intake-temperature information

S913 coolant temperature at inlet of electric water pump within predetermined range?

S914 keep valve opening unchanged

S915 calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 19

S1001

read engine operating condition (engine speed and load) and respective coolant temperatures

S1002

in stratified charge combustion mode?

S1003

set desired coolant temperature for stratified charge combustion mode

S1004

set desired coolant temperature for uniform charge combustion mode

S1005

coolant temperature at inlet of electric water pump within predetermined range?

S1006

keep valve opening unchanged

S1007

calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

Fig. 20

S1101

read engine operating condition (engine speed and load) and respective coolant temperatures

S1102

in lean-burn mode?

S1103

set desired coolant temperature for lean-burn mode

S1104

set desired coolant temperature for stoichiometric combustion mode

S1105

coolant temperature at inlet of electric water pump within predetermined range?

S1106

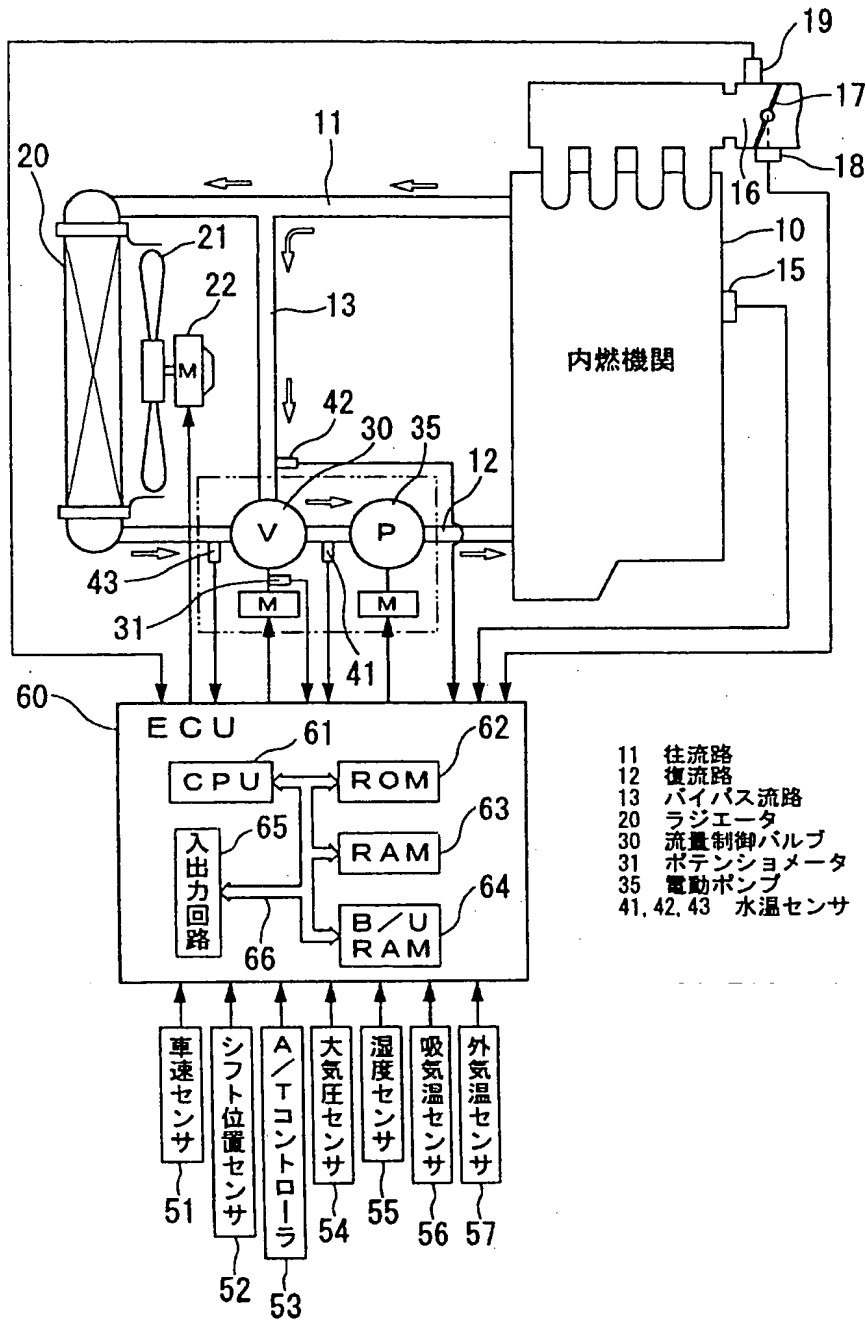
keep valve opening unchanged

S1107

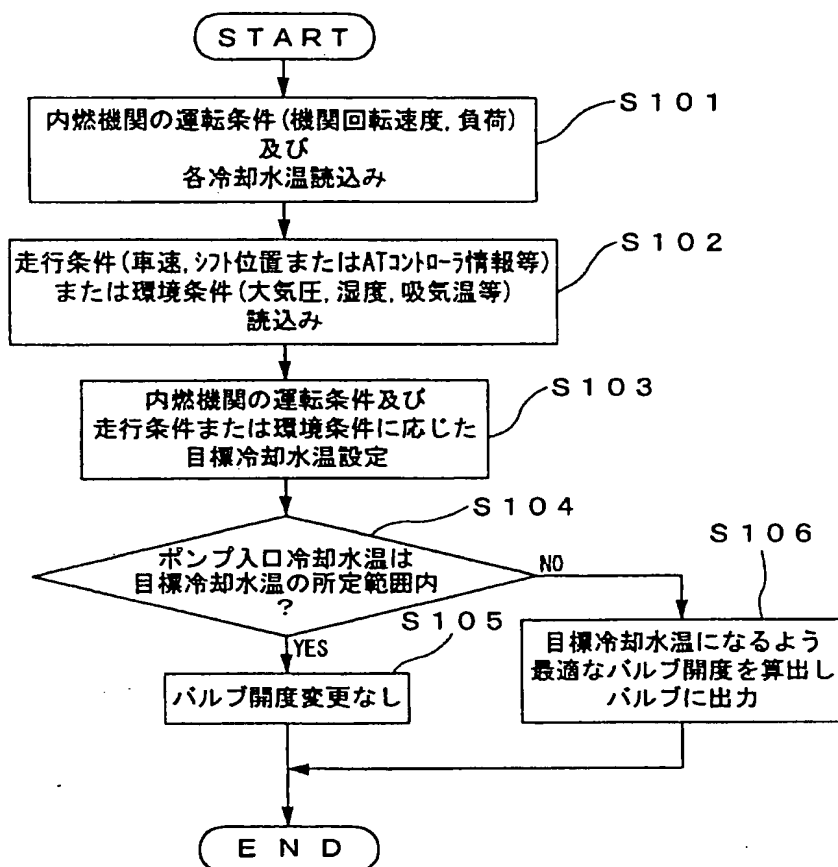
calculate optimum valve opening to obtain desired coolant temperature and output calculated opening to valve

【書類名】 図面

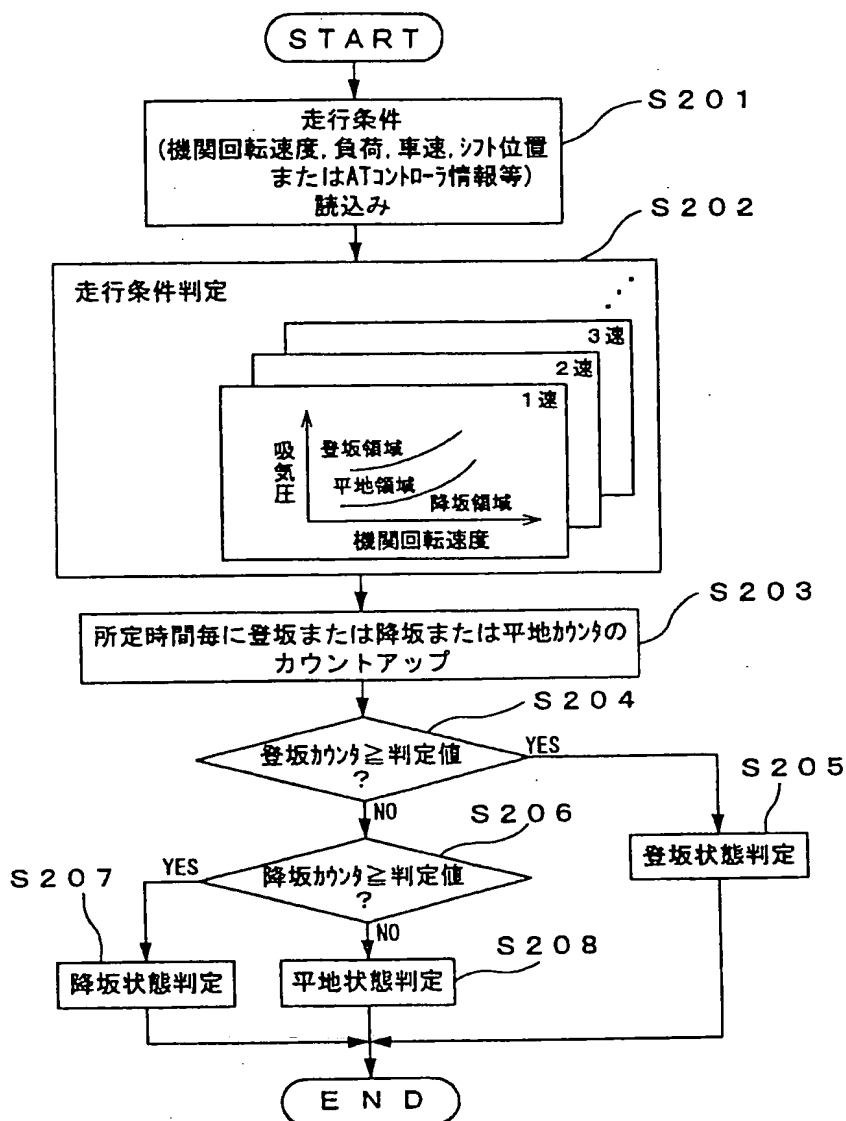
【図1】



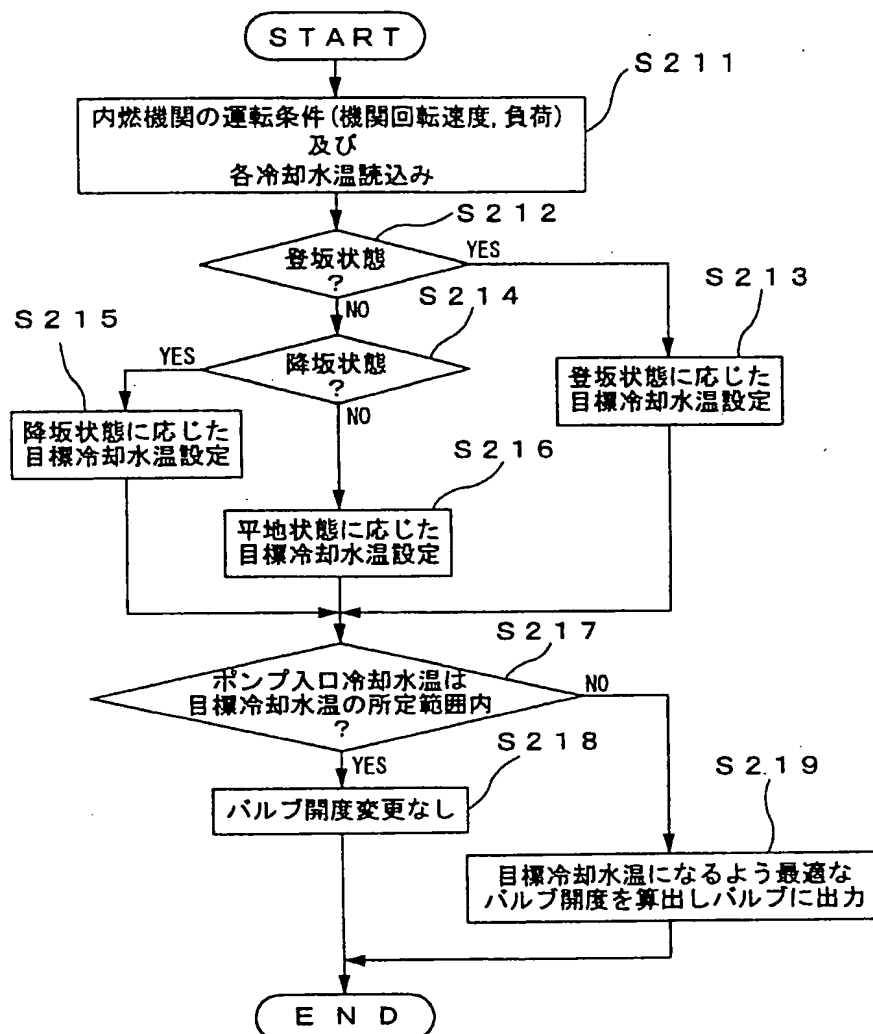
【図2】



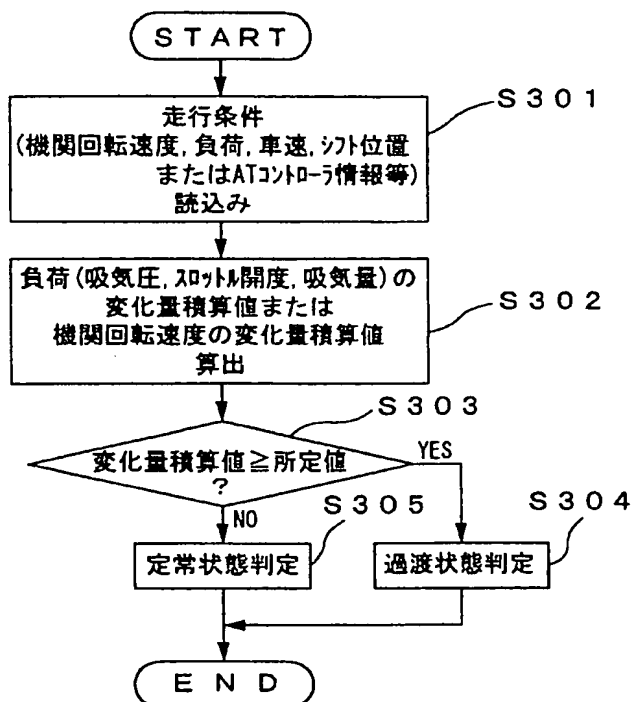
【図3】



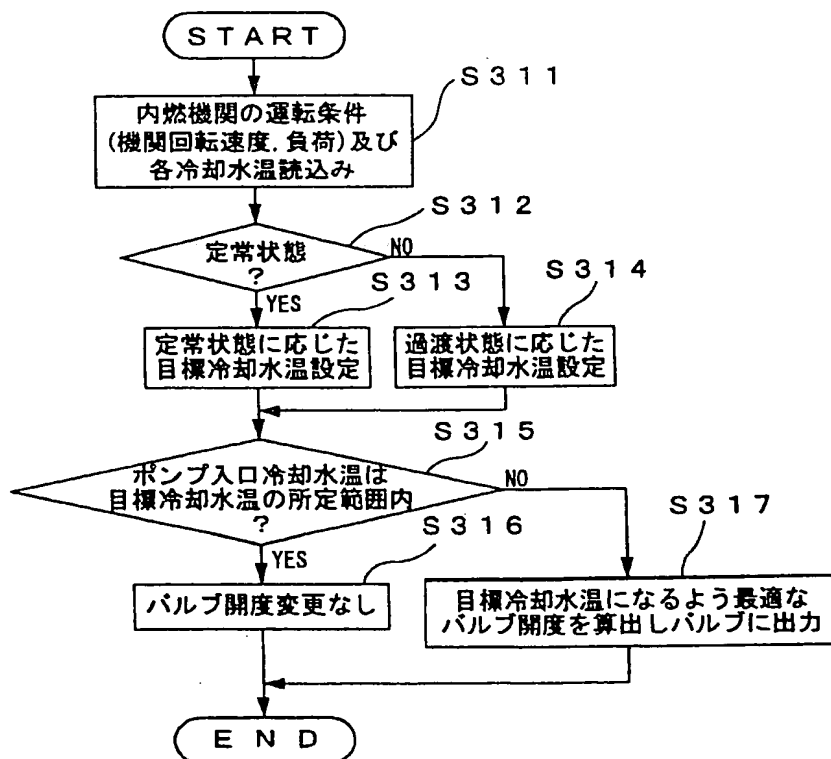
【図4】



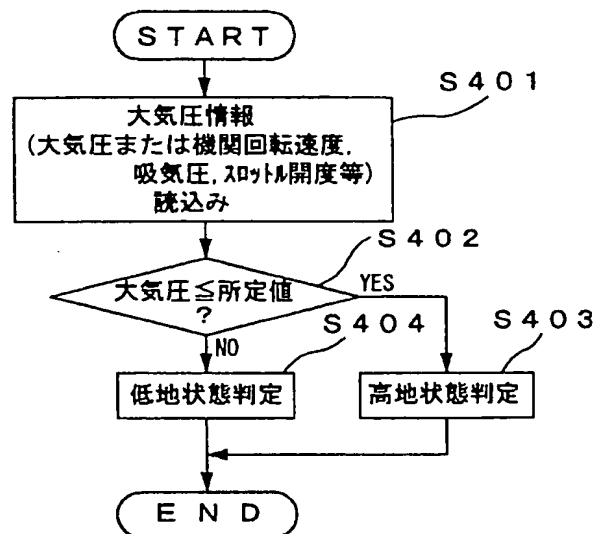
【図5】



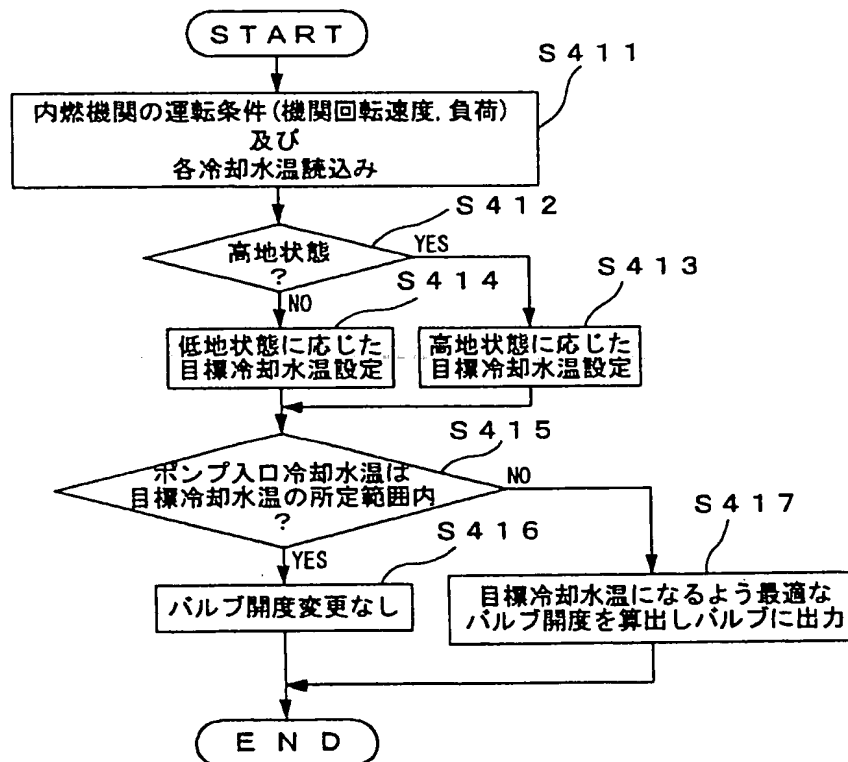
【図6】



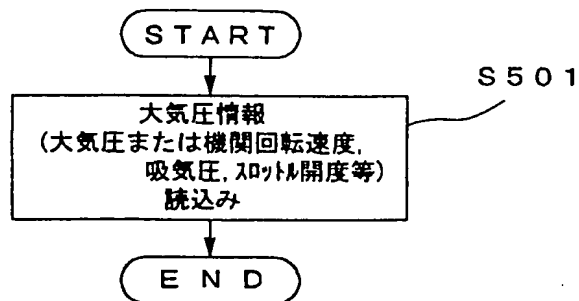
【図7】



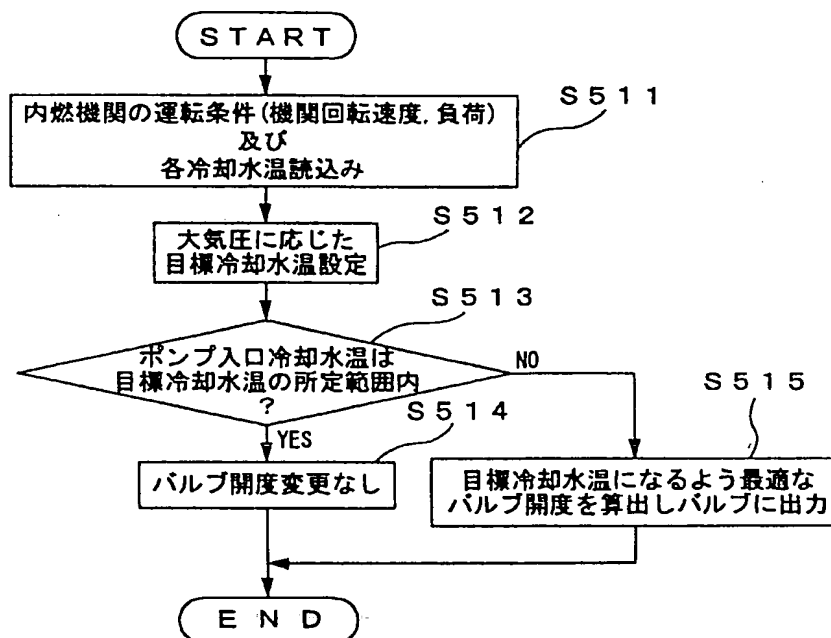
【図8】



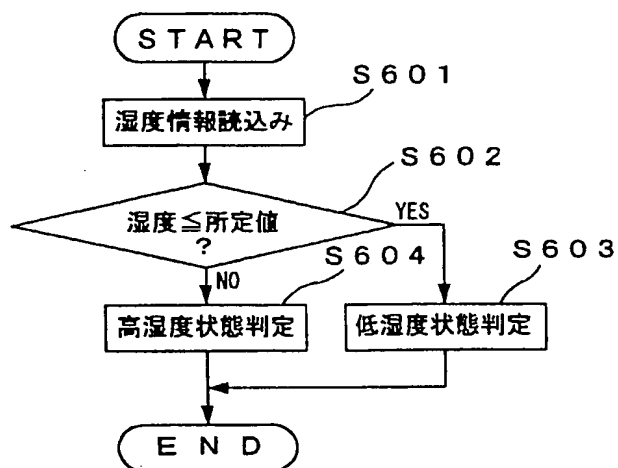
【図9】



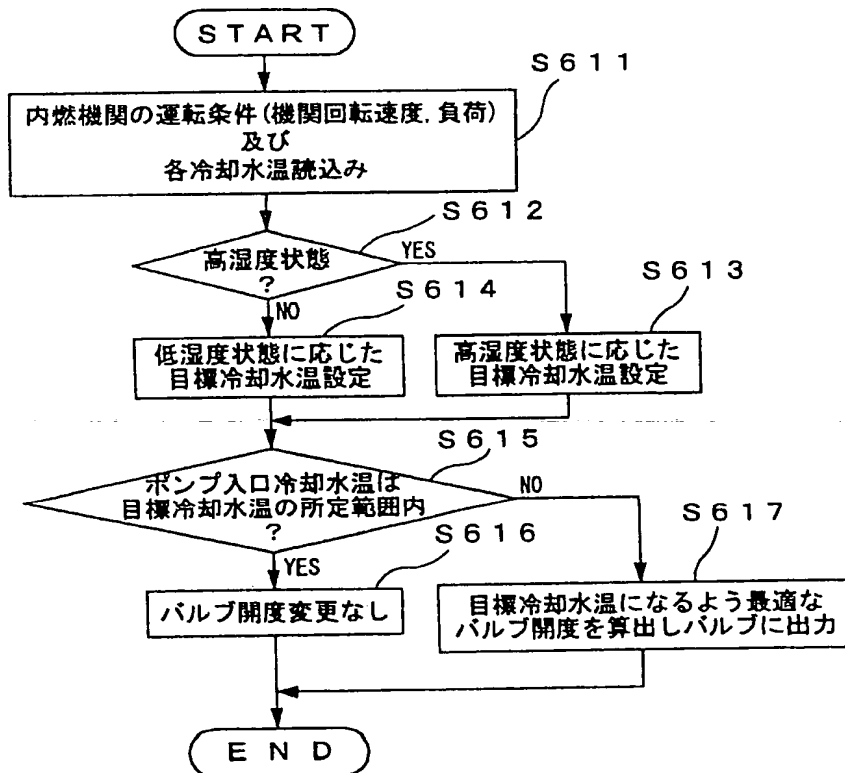
【図10】



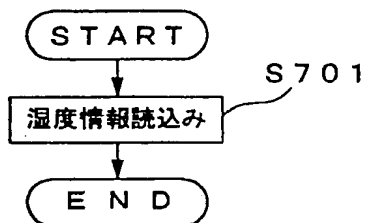
【図11】



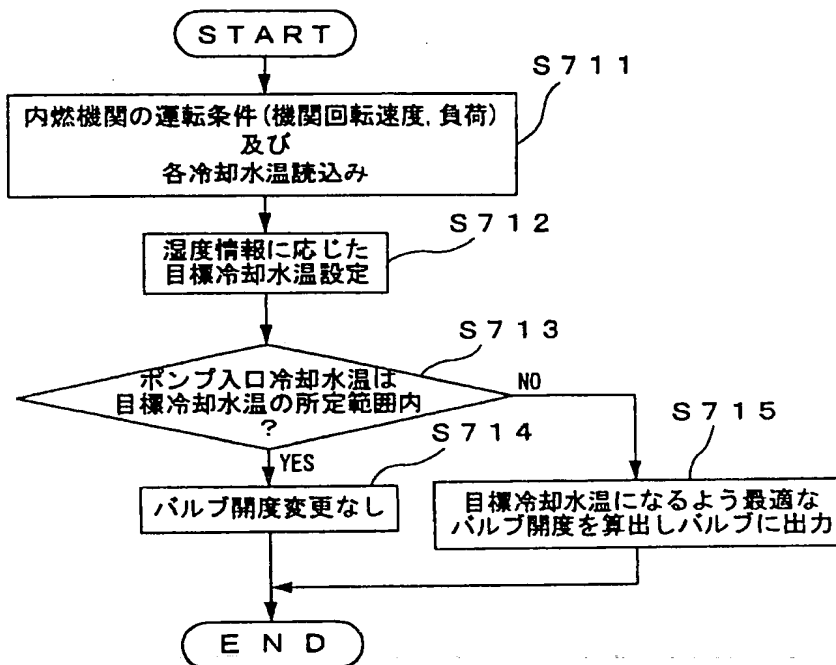
【図12】



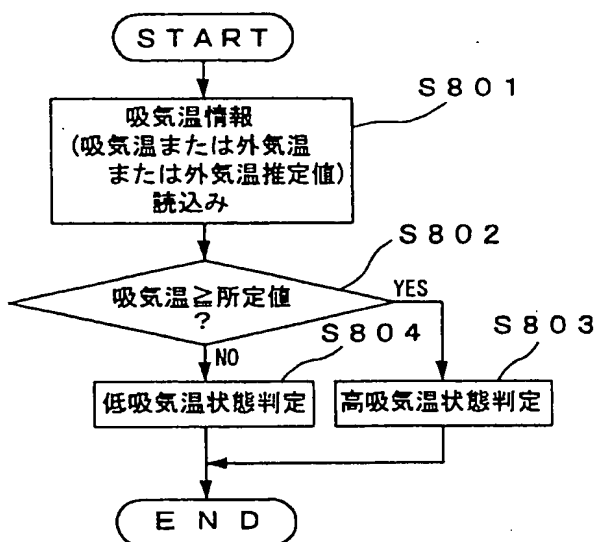
【図13】



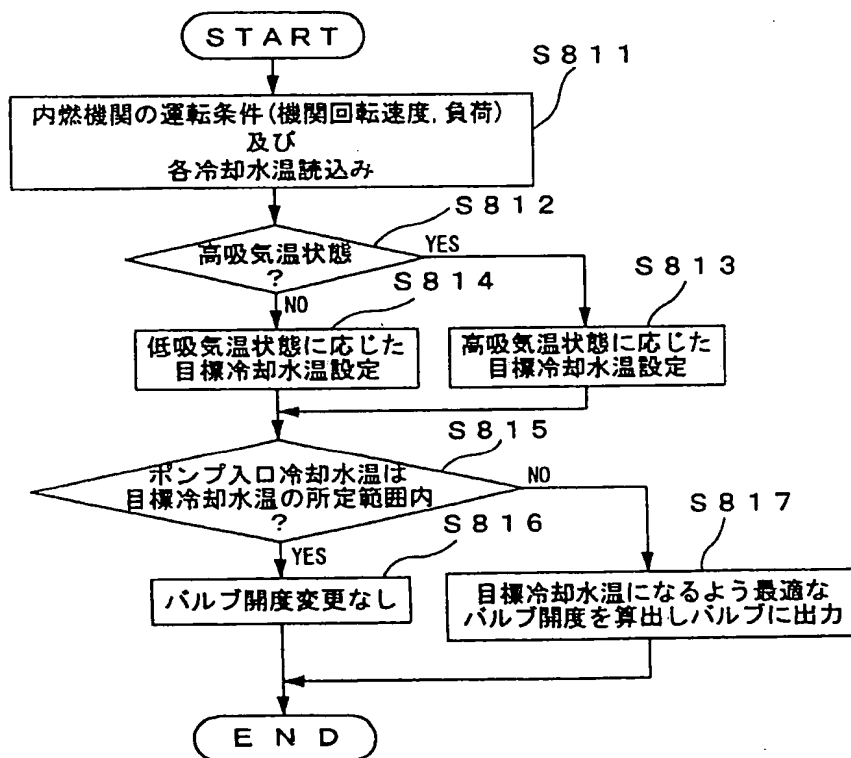
【図14】



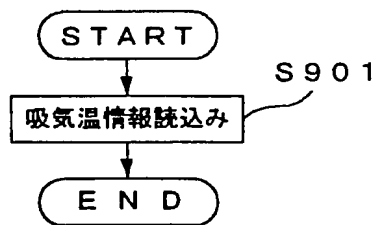
【図15】



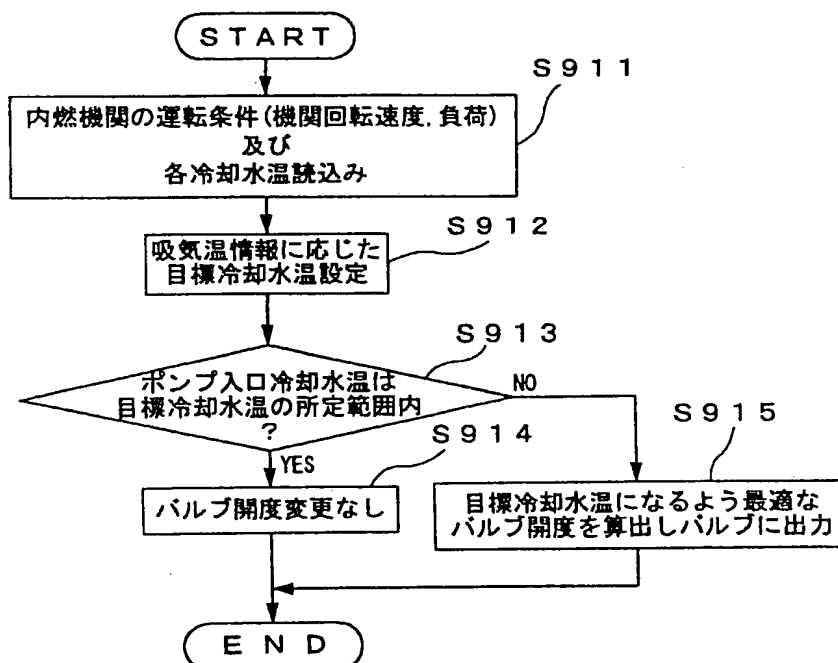
【図16】



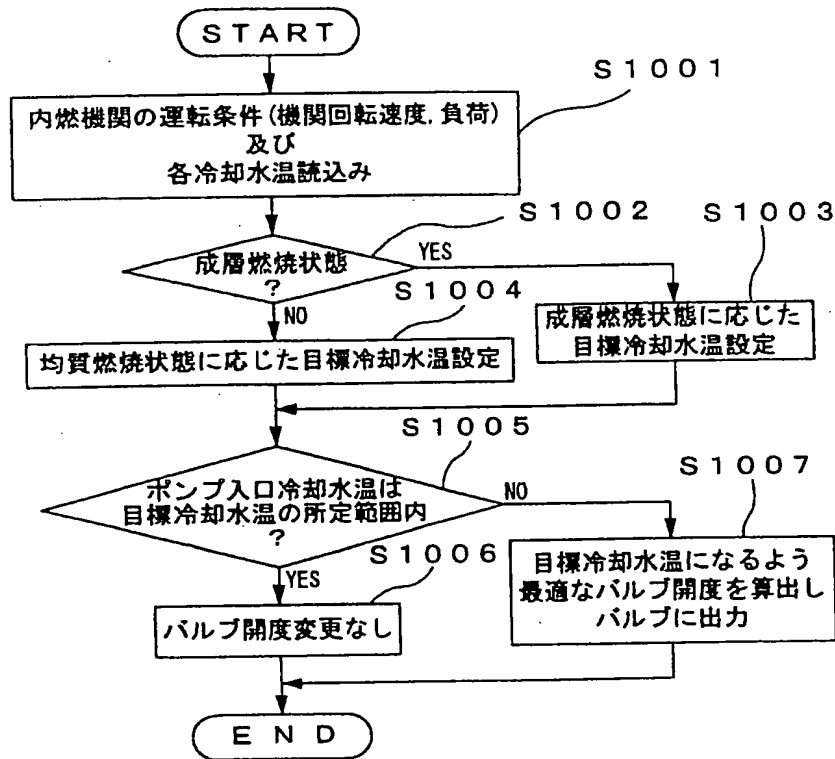
【図17】



【図18】



【図19】



【図20】

